

ACTIVE CUBE

Application manual
Safe Torque Off



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1 General information about the documentation

The present documentation complements the operating instructions and the Quick Start Guide of the frequency inverter ACTIVE Cube (ACU).

1.1 Instruction manuals

For better clarity, the documentation is structured according to the customer-specific requirements made on the frequency inverter.

Quick start guide

The Quick Start Guide describes the basic steps required for mechanical and electrical installation of the frequency inverter. The guided commissioning supports you in the selection of necessary parameters and the configuration of the frequency inverter by the software.

Operating instructions

The Operating Instructions describe and document all functions of the frequency inverter. The parameters required for adapting the frequency inverter to specific applications as well as the wide range of additional functions are described in detail.

Application manual

The application manual supplements the documentation for purposeful installation and commissioning of the frequency inverter. Information on various subjects connected with the use of the frequency inverter is described specific to the application.

If you need a copy of the documentation or additional information, contact your local representative of BONFIGLIOLI.

The present documentation was prepared with great care and it was subjected to extensive and repeated reviews. For reasons of clarity, it was not possible to include all details of all types of the product in the documentation. Neither was it possible to consider all conceivable installation, operation or maintenance situations. If you require further information or if you meet with specific problems which are not dealt with in sufficient detail in the documentation, contact your local BONFIGLIOLI agent.

We would also like to point out that the contents of this documentation do not form part of any previous or existing agreement, assurance or legal relationship. Neither are they intended to supplement or replace such agreements, assurances or legal relationships. The manufacturer's obligations are exclusively specified in the relevant purchase contract. This contract also contains all and any warranty regulations which may apply to the relevant scope of supply. These contractual warranty provisions are neither extended nor limited by the specifications contained in this documentation.

The manufacturer reserves the right to correct or amend the specifications, product information and omissions in these operating instructions without notice. The manufacturer shall not be liable for any damage, injuries or costs which may be caused by the aforementioned reasons.

This documentation was written in german language. Other language versions are translated.

1.2 This document

The present documentation complements the operating instructions ACTIVE Cube (ACU). It contains additional safety information and requirements for the operation of ACTIVE Cube (ACU) in safety-oriented applications. Use in safety-oriented machines shall be permissible only after this documentation has been read carefully and understood.

The applicable basic standards as well as application-specific and specific national standards shall also be complied with – the standards referred to in this manual shall also be complied with.

For this reason, make sure you read the user manual carefully.



WARNING

Compliance with the documentation is required to ensure safe operation of the frequency inverter. BONFIGLIOLI VECTRON GmbH shall not be held liable for any damage caused by any non-compliance with the documentation.



In case any problems occur which are not covered by the documentation sufficiently, please contact the manufacturer.

1.3 Warranty and liability

BONFIGLIOLI VECTRON GmbH would like to point out that the contents of this user manual do not form part of any previous or existing agreement, assurance or legal relationship. Neither are they intended to supplement or replace such agreements, assurances or legal relationships. Any obligations of the manufacturer shall solely be based on the relevant purchase agreement which also includes the complete and solely valid warranty stipulations. These contractual warranty provisions are neither extended nor limited by the specifications contained in this documentation.

The manufacturer reserves the right to correct or amend the specifications, product information and omissions in these operating instructions without notice. The manufacturer shall not be liable for any damage, injuries or costs which may be caused by the aforementioned reasons.

In addition to that, BONFIGLIOLI VECTRON GmbH excludes any warranty/liability claims for any personal and/or material damage if such damage is due to one or more of the following causes:

- inappropriate use of the frequency inverter,
- non-compliance with the instructions, warnings and prohibitions contained in the documentation,
- unauthorized modifications of the solar inverter,
- insufficient monitoring of parts of the machine/plant which are subject to wear,
- repair work at the machine/plant not carried out properly or in time,
- catastrophes by external impact and Force Majeure.

1.4 Obligation

This user manual must be read before commissioning and complied with. Anybody entrusted with tasks in connection with the

- transport,
- assembly,
- installation of the frequency inverter and
- operation of the frequency inverter

must have read and understood the user manual and, in particular, the safety instructions in order to prevent personal and material losses.

1.5 Copyright

In accordance with applicable law against unfair competition, this user manual is a certificate. Any copyrights relating to it shall remain with

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These user manual is intended for the operator of the frequency inverter. Any disclosure or copying of this document, exploitation and communication of its contents (as hardcopy or electronically) shall be forbidden, unless permitted expressly.

Any non-compliance will constitute an offense against the copyright law dated 09 September 1965, the law against unfair competition and the Civil Code and may result in claims for damages. All rights relating to patent, utility model or design registration reserved.

1.6 Storage

The documentation form an integral part of the frequency inverter. It must be stored such that it is accessible to operating staff at all times. In case the frequency inverter is sold to other users, this user manual must also be handed over.

2 General safety instructions and information on use

The chapter "General safety instructions and information on use" contains general safety instructions for the Operator and the Operating Staff. At the beginning of certain main chapters, some safety instructions are included which apply to all work described in the relevant chapter. Special work-specific safety instructions are provided before each safety-relevant work step.

2.1 Terminology

According to the documentation, different activities must be performed by certain persons with certain qualifications.

The groups of persons with the required qualification are defined as follows:

Operator

This is the entrepreneur/company who/which operates the frequency inverter and uses it as per the specifications or has it operated by qualified and instructed staff.

Operating staff

The term Operating Staff covers persons instructed by the Operator of the frequency inverter and assigned the task of operating the frequency inverter.

Qualified staff

The term Qualified Staff covers staff who is assigned special tasks by the Operator of the frequency inverter, e.g. installation, maintenance and service/repair and troubleshooting. Based on their qualification and/or know-how, qualified staff must be capable of identifying defects and assessing functions.

Qualified electrician

The term Qualified Electrician covers qualified and trained staff who has special technical know-how and experience with electrical installations. In addition, Qualified Electricians must be familiar with the applicable standards and regulations, they must be able to assess the assigned tasks properly and identify and eliminate potential hazards.

Instructed person

The term Instructed Person covers staff who was instructed and trained about/in the assigned tasks and the potential hazards that might result from inappropriate behavior. In addition, instructed persons must have been instructed in the required protection provisions, protective measures, the applicable directives, accident prevention regulations as well as the operating conditions and verified their qualification.

Expert

The term Expert covers qualified and trained staff who has special technical know-how and experience relating to frequency inverter. Experts must be familiar with the applicable government work safety directives, accident prevention regulations, guidelines and generally accepted rules of technology in order to assess the operationally safe condition of the frequency inverter.

2.2 Designated use

The frequency inverter is designed according to the state of the art and recognized safety regulations.

The frequency inverters are electrical drive components intended for installation in industrial plants or machines. Commissioning and start of operation is not allowed until it has been verified that the machine meets the requirements of the EC Machinery Directive 2006/42/EC and DIN EN 60204-1.

The frequency inverters meet the requirements of the low voltage directive 2006/95/EEC and DIN EN 61800-5-1. CE-labeling is based on these standards. Responsibility for compliance with the EMC Directive 2004/108/EC lies with the operator. Frequency inverters are only available at specialized dealers and are exclusively intended for commercial use as per EN 61000-3-2.

No capacitive loads may be connected to the frequency inverter.

The technical data, connection specifications and information on ambient conditions are indicated on the rating plate and in the documentation and must be complied with in any case.

2.3 Misuse

Any use other than that described in "Designated use" shall not be permissible and shall be considered as misuse.

For example, the machine/plant must not be operated

- by uninstructed staff,
- while it is not in perfect condition,
- without protection enclosure (e.g. covers),
- without safety equipment or with safety equipment deactivated.

The manufacturer shall not be held liable for any damage resulting from such misuse. The sole risk shall be borne by the operator.

2.3.1 Explosion protection

The frequency inverter is an IP 20 protection class device. For this reason, use of the device in explosive atmospheres is not permitted.

2.4 Residual risks

Residual risks are special hazards involved in handling of the frequency inverter which cannot be eliminated despite the safety-compliant design of the device. Residual risks are not obviously identifiable and can be a potential source of injury or health hazard.

Typical residual hazards include:

Electrical hazard

Danger of contact with energized components due to a defect, opened covers or enclosures or improper working on electrical equipment.

Danger of contact with energized components inside of the frequency inverter if no external disconnection device was installed by the operator.

Electrostatic charging

Touching electronic components bears the risk of electrostatic discharges.

Thermal hazards

Risk of accidents by hot machine/plant surfaces, e.g. heat sink, transformer, fuse or sine filter.

Charged capacitors in DC link

The DC link may have dangerous voltage levels even up to three minutes after shutdown.

Danger of equipment falling down/over, e.g. during transport

Center of gravity is not the middle of the electric cabinet modules.

2.5 Safety and warning signs at frequency inverter

- Comply with all safety instructions and danger information provided on the frequency inverter.
- Safety information and warnings on the frequency inverter must not be removed.

2.6 Warning information and symbols used in the user manual

2.6.1 Hazard classes

The following hazard identifications and symbols are used to mark particularly important information:



DANGER

Identification of immediate threat holding a **high** risk of death or serious injury if not avoided.



WARNING

Identification of immediate threat holding a **medium** risk of death or serious injury if not avoided.



CAUTION

Identification of immediate threat holding a **low** risk of minor or moderate physical injury if not avoided.

NOTE

Identification of a threat holding a risk of material damage if not avoided.

2.6.2 Hazard symbols

Symbol	Meaning	Symbol	Meaning
	General hazard		Suspended load
	Electrical voltage		Hot surfaces

2.6.3 Prohibition signs

Symbol	Meaning
	No switching; it is forbidden to switch the machine/plant, assembly on

2.6.4 Personal safety equipment

Symbol	Meaning
	Wear body protection

2.6.5 Recycling

Symbol	Meaning
	Recycling, to avoid waste, collect all materials for reuse

2.6.6 Grounding symbol

Symbol	Meaning
	Ground connection

2.6.7 ESD symbol

Symbol	Meaning
	ESD: Electrostatic Discharge (can damage components and assemblies)

2.6.8 Information signs

Symbol	Meaning
	Tips and information making using the frequency inverter easier.

2.7 Directives and guidelines to be adhered to by the operator

The operator must follow the following directives and regulations:

- Ensure that the applicable workplace-related accident prevention regulations as well as other applicable national regulation are accessible to the staff.
- An authorized person must ensure, before using the frequency inverter, that the device is used in compliance with its designated use and that all safety requirements are met.
- Additionally, comply with the applicable laws, regulations and directives of the country in which the frequency inverter is used.
- Any additional guidelines and directives that may be required additionally shall be defined by the operator of the machine/plant considering the operating environment.

2.8 Operator's general plant documentation

- In addition to the user manual, the operator should issue separate internal operating instructions for the frequency inverter. The user manual of the frequency inverter must be included in the user manual of the whole plant.

2.9 Operator's/operating staff's responsibilities

2.9.1 Selection and qualification of staff

- Any work on the frequency inverter may only be carried out by qualified technical staff. The staff must not be under the influence of any drugs. Note the minimum age required by law. Define the staff's responsibility in connection with all work on the frequency inverter clearly.
- Work on the electrical components may only be performed by a qualified electrician according to the applicable rules of electrical engineering.
- The operating staff must be trained for the relevant work to be performed.

2.9.2 General work safety

- In addition to the user manual of the machine/plant, any applicable legal or other regulations relating to accident prevention and environmental protection must be complied with. The staff must be instructed accordingly.
Such regulations and/or requirements may include, for example, handling of hazardous media and materials or provision/use of personal protective equipment.
- In addition to this user manual, issue any additional directives that may be required to meet specific operating requirements, including supervision and reporting requirements, e.g. directives relating to work organization, workflow and employed staff.
- Unless approved of expressly by the manufacturer, do not modify the frequency inverter in any way, including addition of attachments or retrofits.
- Only use the frequency inverter if the rated connection and setup values specified by the manufacturer are met.
- Provide appropriate tools as may be required for performing all work on the frequency inverter properly.

2.10 Organizational measures

2.10.1 General

- Train your staff in the handling and use of the frequency inverter and the machine/plant as well as the risks involved.
- Use of any individual parts or components of the frequency inverter in other parts of the operator's machine/plant is prohibited.
- Optional components for the frequency inverter must be used in accordance with their designated use and in compliance with the relevant documentation.

2.10.2 Use in combination with third-party products

- Please note that BONFIGLIOLI VECTRON GmbH will not accept any responsibility for compatibility with third-party products (e.g. motors, cables or filters).
- In order to enable optimum system compatibility, BONFIGLIOLI VECTRON GmbH office components facilitating commissioning and providing optimum synchronization of the machine/plant parts in operation.
- If you use the frequency inverter in combination with third-party products, you do this at your own risk.

2.10.3 Transport and Storage

- The frequency inverters must be transported and stored in an appropriate way. During transport and storage the devices must remain in their original packaging.
- The units may only be stored in dry rooms which are protected against dust and moisture and are exposed to little temperature deviations only. The requirements of DIN EN 60721-3-1 for storage, DIN EN 60721-3-2 for transport and labeling on the packaging must be met.
- The duration of storage without connection to the permissible nominal voltage may not exceed one year.

2.10.4 Handling and installation

- Do not commission any damaged or destroyed components.
- Prevent any mechanical overloading of the frequency inverter. Do not bend any components and never change the isolation distances.
- Do not touch any electronic construction elements and contacts. The frequency inverter is equipped with components which are sensitive to electrostatic energy and can be damaged if handled improperly. Any use of damaged or destroyed components will endanger the machine/plant safety and shall be considered as a non-compliance with the applicable standards.
- Only install the frequency inverter in a suitable operating environment. The frequency inverter is exclusively designed for installation in industrial environments.
- If seals are removed from the case, this can result in the warranty becoming null and void.

2.10.5 Electrical connections

- The five safety rules must be complied with.
- Never touch live terminals. The DC link may have dangerous voltage levels even up to three minutes after shutdown.
- When performing any work on/with the frequency inverter, always comply with the applicable national and international regulations/laws on work on electrical equipment/plants of the country when the frequency inverter is used.
- The cables connected to the frequency inverters may not be subjected to high-voltage insulation tests unless appropriate circuitry measures are taken before.
- Only connect the frequency inverter to suitable supply mains.

2.10.5.1 The five safety rules

When working on/in electrical plants, always follow the five safety rules:

1. Isolate
2. Secure to prevent restarting
3. Check isolation
4. Earth and short-circuit,
5. Cover or shield neighboring live parts.

2.10.6 Safe operation

- During operation of the frequency inverter, always comply with the applicable national and international regulations/laws on work on electrical equipment/plants.
- Before commissioning and the start of the operation, make sure to fix all covers and check the terminals. Check the additional monitoring and protective devices according to the applicable national and international safety directives.
- During operation, never open the machine/plant
- Do not connect/disconnect any components/equipment during operation.
- The machine/plant holds high voltage levels during operation, is equipped with rotating parts (fan) and has hot surfaces. Any unauthorized removal of covers, improper use, wrong installation or operation may result in serious injuries or material damage.
- Some components, e.g. the heat sink or brake resistor, may be hot even some time after the machine/plant was shut down. Don't touch any surfaces directly after shutdown. Wear safety gloves where necessary.
- The frequency inverter may hold dangerous voltage levels until the capacitor in the DC link is discharged. Wait for at least 3 minutes after shutdown before starting electrical or mechanical work on the frequency inverter. Even after this waiting time, make sure that the equipment is deenergized in accordance with the safety rules before starting the work.
- In order to avoid accidents or damage, only qualified staff and electricians may carry out the work such as installation, commissioning or setup.
- In the case of a defect of terminals and/or cables, immediately disconnect the frequency inverter from mains supply.
- Persons not familiar with the operation of frequency inverters must not have access to the frequency inverter. Do not bypass nor decommission any protective facilities.
- The frequency inverter may be connected to power supply every 60 s. This must be considered when operating a mains contactor in jog operation mode. For commissioning or after an emergency switch-off, a non-recurrent, direct restart is permissible.
- After a failure and restoration of the power supply, the motor may start unexpectedly if the Auto Start function is activated.
If staff is endangered, a restart of the motor must be prevented by means of external circuitry.
- Before commissioning and the start of the operation, make sure to fix all covers and check the terminals. Check the additional monitoring and protective devices according to EN 60204 and applicable the safety directives (e.g. Working Machines Act or Accident Prevention Directives).

2.10.7 Maintenance and service/troubleshooting

- Visually inspect the frequency inverter when carrying out the required maintenance work and inspections at the machine/plant.
- Perform the maintenance work and inspections prescribed for the machine carefully, including the specifications on parts/equipment replacement.
- Work on the electrical components may only be performed by a qualified electrician according to the applicable rules of electrical engineering. Only use original spare parts.
- Unauthorized opening and improper interventions in the machine/plant can lead to personal injury or material damage. Repairs on the frequency inverters may only be carried out by the manufacturer or persons authorized by the manufacturer. Check protective equipment regularly.
- Before performing any maintenance work, the machine/plant must be disconnected from mains supply and secured against restarting. The five safety rules must be complied with.

2.10.8 Final decommissioning

Unless separate return or disposal agreements were made, recycle the disassembled frequency inverter components:

- Scrap metal materials
- Recycle plastic elements
- Sort and dispose of other component materials



Electric scrap, electronic components, lubricants and other utility materials must be treated as special waste and may only be disposed of by specialized companies.



In any case, comply with any applicable national disposal regulations as regards environmentally compatible disposal of the frequency inverter. For more details, contact the competent local authorities.

3 Safety Instructions on Function „Safe Torque Off“ (STO)

The function “Safe Torque Off” (STO) is a functional safety provision, i.e. it protects staff from damage, provided that projecting, installation and operation are performed properly. This function does not disconnect the plant from power supply.

The safety function “Safe torque off” (STO) can be used to realize an “Emergency Stop” according to EN 60204 while the power supply is still active on the frequency inverter

A provision must be provided for disconnecting the machine from power supply for maintenance work.

WARNING

Improper installation of the safety technique can cause an uncontrolled starting of the drive. This may cause death, serious injuries and significant material damage.

Safety functions may only be installed and commissioned by qualified staff.

The Standard EN 60204 separates EMERGENCY SWITCH OFF and EMERGENCY STOP. EMERGENCY SWITCH OFF means the electrical disconnection of the frequency inverter from the supply source. An EMERGENCY SWITCH OFF can be realized by installing a switch disconnecter in example.

EMERGENCY STOP provides the possibility to achieve a safe state of the frequency inverter while maintaining the supply voltage.

Depending on the application, other components may be necessary to achieve a safe state in addition to “Safe Torque Off (STO)” of the frequency inverter.

An EMERGENCY STOP according to EN 60204 must be functioning in all operation modes of the application.

Resetting of an EMERGENCY STOP or an EMERGENCY SWITCH OFF must not result in uncontrolled starting of the drive.

The drive is started again when the function STO is no longer triggered. In order to comply with EN 60204, it must be ensured by taking external measures that the drive does not start without prior confirmation.

Without a mechanical brake, the drive might not stop immediately but coast to a standstill. If this may result in personal or material damage, additional safety measures must be taken.

If persons may be endangered after disconnection of the motor control by STO, access to the hazard areas must be prevented until the drive has stopped.

Check the safety function at regular intervals according to the results of your risk assessment. BONFIGLIOLI VECTRON recommends that the check is performed after one year, at the latest.

The STO function is one fault fail-safe. No single fault or component failure can cause a disabled drive to produce motor shaft torque. Only in extremely unlikely combinations of component faults the motor shaft could move jerky with sudden acceleration (maximum $180^\circ/\text{number of pole pairs}$, for example jerky movement of 90° for 4-pole motor, $180^\circ/2$) and produce torque. It must be checked if this behavior can cause a dangerous machine movement.

If the STO function is used, the special safety, installation and instructions on use instructions shall be complied with.



Comply with the Application manual „Safe Torque Off STO“, especially when the described safety relevant function is used.

**⚠ Warning! Dangerous voltage!**

After disconnection of an external DC 24 V power supply, the DC link of the frequency inverter is still connected to mains supply.

Even if the motor control is deactivated and the motor is coasting to a standstill or has already stopped, high voltages may still be present on the motor terminals.

Before working (e.g. maintenance) on live parts, the machine must always be disconnected from mains supply (main switch). This must be documented on the machine.

When the function “Safe Torque Off” is triggered, the motor is not isolated from the DC link of the frequency inverter. High voltage levels may be present at the motor.

Do not touch live terminals.

Permanent magnet synchronous motors (PMSM) must be operated only up to the synchronous speed. PMSM cannot be operated above the synchronous speed because the trigger of the STO function can lead to the destruction of the power stage.

3.1 Approved Devices

All ACU devices of sizes 1 to 7 are approved for applications with functional safety according to this manual.

For ACU of size 8 the certification of the function “Safe Torque Off” is in preparation.

The information of the size you can refer to the operating manual and the Quick Start Guide.

4 Information of Risk Analysis and Risk Assessment

According to the Directive on Machinery 98/37/EC, the manufacturer of a machine is obliged to carry out a risk analysis in order to identify the hazards related to the machine.

The Standard EN 14121-1 – Safety of machinery - Risk assessment – Principles – describes the information required for risk assessment.

Risk assessment is effected according to the following criteria:

- degree of injury (serious/minor)
- frequency or duration of stay (frequent/seldom)
- possibilities of avoidance (hardly possible/possible)

For defined risks the Standards EN ISO 13849-1, IEC 61508 or EN 954-1 can be used to accomplish a correct classification into Safety category, SIL (Safety Integrated Level) or PL (Performance Level). These standards contain design principles for safety-relevant parts of control systems.

In the case of the safety function “Safe Torque Off”, the risk assessment must consider the fact that the motor will coast to a standstill in the case of an error. Depending on the application, a mechanical brake may be required.

Responsibility:

The **Manufacturer** shall be responsible for the safety of the machine.

- risk analysis of hazards originating from the machine
- measures for reduction and elimination of the risks
- documentation of residual risk from the point of view of the manufacturer
- selection of suitable controller, installation of protective equipment, ergonomics, documentation, warning of remaining risks

The **operator** of the machine is responsible for the safety of the application.

- risk analysis of hazards originating from the use of the machine
- documentation of residual risk from the point of view of the operator
- safe operation and protection of operating staff (barriers, instruction of operating staff, etc.)

Selection of safety function:

- Risk analysis and risk assessment for machine (standards EN 12100-1, EN 12100-2 and EN 14121-1)
- Risk reduction by machine design
- If not possible by design: risk reduction by protective equipment
- Identification of safety requirements
- Selection of category of safety function
 - PL d according to EN ISO 13849-1
 - SIL 2 according to IEC 61508
 - Category 3 according to EN 954-1



The Standard EN954-1 was replaced by the legislator with the standard EN ISO 13849-1.

5 General Description of Safety Function

5.1 Integrated Safety Function

Electronic protection systems are integrated in the drive control system and perform safety functions in order to minimize or eliminate hazards caused by functional errors of machines.

The integrated safety functions replace time-consuming and expensive installation of external safety components.

The safety function can be requested or triggered by an error.

In hazard areas, setup work or work for elimination or errors may be required where the safety function is not to be activated by isolating protection devices such as mains contactors or motor contactors. Here, the additional safety function may be used. STO can be used as an alternative to mains or motor contactors, which can be omitted dependent on the application.

The integrated safety functions reduce the risk of personal damage in hazard areas and reduce installation requirements.

5.2 Functional Safety

The safety function of the control system must be ensured for normal, trouble-free operating states as well as in the case of an error. As a result of this requirement:

- The safety function must be checked in case errors are present. Possible methods include: error tree analysis, FMEA, etc.).

5.3 Classification the safety requirement

The integrated safety function “Safe Torque Off” of the ACU frequency inverter meets the following requirements:

- up to safety integrity level SIL 2 according to DIN EN 61508 for STO (STO, Safe Torque Off according to EN 61800-5-2)
- of category 3 according to DIN EN 954-1 (safe stop)
- up to performance level d according to EN 13849-1

In the case of an error, thanks to the safety function STO, the frequency inverter does not supply energy to the motor which would cause a revolution or torque (or a movement or force in the case of a linear motor).

Characteristic for the classification mentioned above:

- If an error occurs, the safety function is maintained.

–

By using appropriate safety control devices, stop category 0 and stop category 1 according to EN 60204 can be achieved in the machine. For safety control devices, please refer to chapter 10.

Stop category 0: Stop by immediate disconnection of energy supply to the machine drive elements, i.e. uncontrolled stop.

Stop category 1: Controlled stop, where energy is still being supplied to the drive elements of the machine to perform the stopping operation. Energy supply is stopped only after the drive has come to a standstill.

Note that the drive may not stop immediately but coast to a standstill. If no mechanical brake is installed, or a defective brake may involve a risk, further protective measures (in example tumbler) are to be taken.

6 Description of ACTIVE Cube Safety Function

The frequency inverters of the ACU series of devices feature the integrated safety function „Safe torque off, STO“.

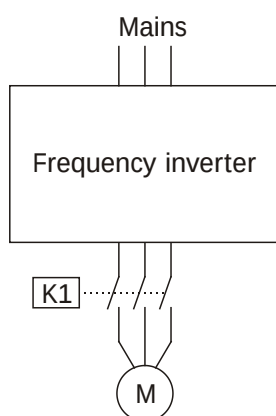
In the case of an error or if requested, the power semiconductors of the frequency inverter will be switched off. After this, the frequency inverter does not supply energy to the drive which would cause a revolution or a torque (or a movement or force in the case of a linear drive). Mains voltage is still present. The function STO can be used, for example, for safe stopping in the case of a dangerous situation or for maintenance work on the machine. If an error occurs, the machine can still be (or remain) switched off safely.

Unlike shut-down via mains contactors or motor contactors, the integrated safety function enables easy combination of drives in a machine to form functional groups. The Safe Torque Off can be limited to certain plant areas in this way. Another advantage is the fact that it is not necessary to wait until the frequency inverter has been charged and discharged. Thus, readiness of the machine for operation can be restored more quickly. Regular electro mechanic equipment are wearing out – through the usage of the STO functionality, this kind of equipment is no longer necessary and maintenance costs can be reduced.

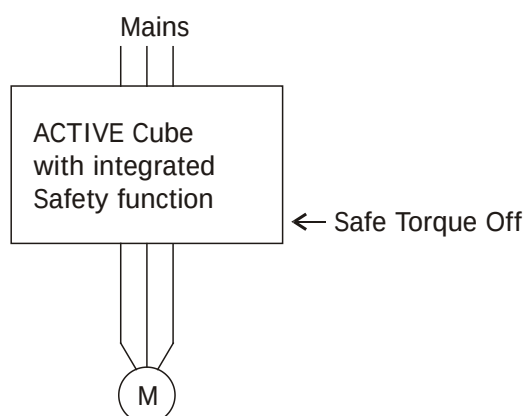
Safe Torque Off:

- Energy supply for the rotary field of the motor is interrupted; the motor coasts to a standstill
- Used if monitoring for standstill is not required
- Accidental start of the motor is prevented
- No galvanic isolation of motor from frequency inverter DC link

Traditional System



**Integrated System
with ACU and usage of STO**



Further advantages:

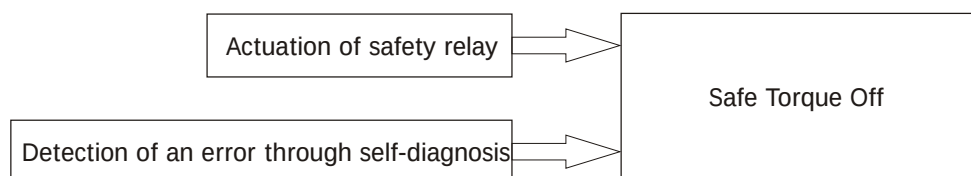
- Contactors on motor side not required, reduced installation requirements, less components, more space in electrical cabinet
- Simple realization with external safety control device
- The drive can be connected to power supply continuously; communication and parameter configuration of the frequency inverter are maintained while the torque is disabled.
- Easier machine approval, because the safety function is certified via a type examination check.



Triggering of function “Safe Torque Off”

Safe Torque Off can be achieved by:

- Intentional triggering during operation in order to stop a drive and safely prevent restarting, e.g. for maintenance work on a machine.
- Triggering by actuation of an emergency stop switch or monitoring of protective systems, e.g. safety door.
- Detection of an error. The drive may only start again after the error has been acknowledged and eliminated.



Application example:

The danger zone near a transport conveyor is monitored by a light grid. If anybody enters the danger zone, the light grid is interrupted. The DC 24 V supply for the digital inputs STO of the function „Safe Torque Off“ is switched off and the frequency inverter output stage is disabled. The drive coasts to a standstill. Disconnection from mains supply is not necessary. Communication via field bus or addressing via the terminals is still possible. An external brake which stops the motor can be addressed.

6.1 Two-Channel Monitoring

The STO function (Safe torque off) is realized via two channels in the frequency inverter (redundant design). Via two redundant monitored stop paths with no-voltage release (STOA and STOB), the frequency inverter is switched off safely even if an error occurs and the control voltage fails at the same time. Thus, the drive is stopped safely if an error occurs. An error is identified and can then be repaired (e.g. by replacing of a unit). Triggering can be effected, for example, via a two-channel contactor control with two release circuits and redundant disconnection of the main current or via a sensor or emergency stop switch with two contacts and separate cable routing to the evaluation unit.

The stop paths are monitored cyclically every 32 ms. Both stop paths are designed identically.

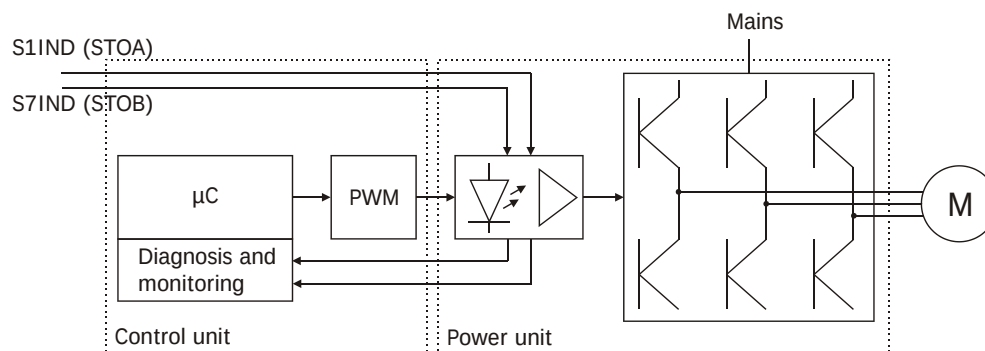
Via the digital inputs S1IND (STOA) and S7IND (STOB), two DC 24 V control voltages of a protection device are applied. If the protection device is actuated, the control voltages are interrupted and the pulse block is activated; energy supply to the motor is switched off. Disconnection is effected at a delay of less than 10 ms.

If the function STO is triggered, the overriding controller has no more influence on the pulse block¹ in the frequency inverter. To restart, the pulse block has to be reset and a release commanded by the operator or the superior PLC.

One single error will not result in a failure of the safety function.

¹ If the pulse block is set, the controller release is reset. If the pulse block is set, no motor revolving field is generated.

Stop paths



The test required for monitoring is performed by the frequency inverter automatically. If the test results negative, the frequency inverter cannot be switched on anymore. Starting is possible again only after the error has been repaired and the next test has been completed successfully.

Truth table

In the truth table, the states of the safety-relevant inputs STOA and STOB for activation and deactivation of the safety function STO are listed.

Truth table		
STOA	STOB	Description of state
0	0	Safety function "Safe Torque Off" (STO) has been triggered. The frequency inverter signals no error in STO function.
0	1	STO is triggered. Monitoring for error in frequency inverter or external circuitry (5-second monitoring). After 5 seconds, an error is signaled.
1	0	
1	1	STO is not triggered. Release for operation.

5-second monitoring

It will be checked if the two inputs STOA or STOB are switched on within an interval of less than 5 sec for requesting the release of the frequency inverter output stages.

If function STO is triggered by removing one of the signals from inputs STOA or STOB, the status changes to "STO triggered". Now, the unit waits that both inputs are switched off. If this has not been done within 5 s after occurrence of this state, an error is triggered (5-second monitoring).

If, during operation, an error is detected, the output stage is switched off, the release is reset ("0") and the frequency inverter signals an error. This status can only be left by switching off ("0") the two release inputs STOA and STOB.

- Different signal states on inputs STOA or STOB start the 5-second monitoring
- Within 5 seconds, the same signal must be present of both inputs, otherwise an error will be signaled (F1205)

The function of external installation can be checked via the "5-second monitoring" by actuating the protection device.

Behavior of frequency inverter after start

- Initialization
- Monitoring for release request (5-second monitoring)
- Preparation of release (check of stop paths)
- Release of frequency inverter

Behavior of frequency inverter in the case of an error

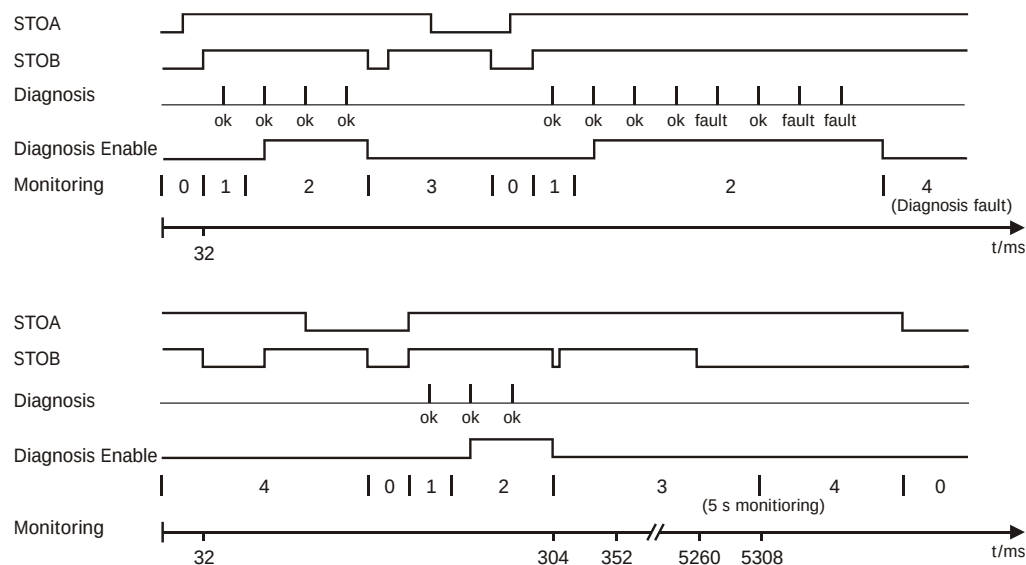
- Switch off of IGBT in power output stage by disconnection of optocoupler supply voltage
- Suppression of control pulses of IGBT
- Setting of error bit with possibility of transfer to overriding controller
- Setting of digital output for error message
- Release of digital input for error acknowledgement.

6.2 Diagnosis function and enforced dynamizing

The two stop paths are monitored by the frequency inverter every 32 ms. If at least one of the two inputs S1IND (STOA) or S7IND (STOB) is switched off, the pulse block is activated. Additionally, a 5-second monitoring cycle begins for the other stop path. If this path is not stop within 5 s, error F1205 is output.

The test required for monitoring the stop paths is performed by the frequency inverter automatically. Via automated enforced dynamizing, the stop paths are checked for errors. If the test result is negative, the frequency inverter cannot be switched on anymore, and error F1201 is signaled. Starting is possible again only after the error has been repaired and the next diagnosis cycle has been completed successfully.

Sequence of release and monitoring states depending on signals on control inputs STOA and STOB:



Monitoring states

- 0: Monitoring of Enable Actuation
- 1: Preparation Enable
- 2: Enable
- 3: Actuation of STO
- 4: Fault

Diagnosis fault: Only if 2 consecutive faults are recognized, the monitoring function reports a fault.

5 s Monitoring: Checks, if both inputs STOA and STOB are switched on within 5 s from each other.

In order to achieve robust operation and, for example, exclude electromagnetic interference in the signal assessment of the diagnosis function, the diagnosis is repeated when an error is detected. The frequency inverter is switched over only if another error is detected by the diagnosis function in operation status "STO Enable".

Before the frequency inverter output stages are released:

- Check if STOA and STOB are switched on less than 5 s after one another (5s monitoring). If this is the case, the release is prepared.
- Diagnosis for error in stop paths STOA and STOB. If no error is detected in the stop paths and release has been prepared, the output stages are enabled.

6.3 Diagnosis indicators

The LEDs of the frequency inverter indicate if the safety function is activated properly.

LED		Description	Rotary field on motor
green	red		
Off	Off	No supply voltage, unit is off	No
On	On	Initialization and self-test	No
Flashing	Off	Operation mode	No
On	Off	Operating message	Yes
On	Flashing	Warning message in operation	Yes
Flashing	Flashing	Ready for operation and warning message	No
Off	Flashing	Fault message	No
Off	On	Error message can be acknowledged	No

7 Requirements to be met by installation

7.1 Instructions on installation of safety equipment

- If work is to be carried out on live components, it must be possible to disconnect the machine from mains supply by means of a main switch.
- According to EN 61800-5-2 a fault exclusion can be considered with one of the following possibilities:
 - o The conductor is installed permanently and in example protected against external damage with a cable duct or reinforcement.
 - o Single multi-conductors are used.
 - o The conductors are situated in an electrical cabinet.
 - o The conductors are shielded independently and have grounding.If applicable, the requirements of EN 60204-1 have to be considered to install the connectors correctly.
- Protection against dirt is ensured if the ACTIVE Cube frequency inverters and safety control equipment is installed in electrical cabinets with high IP protection, e.g. IP 54.
- If external forces act on the drive axis, e.g. in the case of vertical axes (suspended loads) or round axes with asymmetrical weight distribution, mechanical brakes must be installed additionally.
- Only use voltage sources with safe disconnection (SELV/PELV) according to VDE0100. Comply with the specifications in chapter 7.3.
- The ACTIVE Cube frequency inverters must not be supplied with pulsed signals. Cross fault detection via pulsed signals cannot be used for this reason. Errors can be excluded in the case of the ACTIVE Cube units because the terminal blocks for the STO function are physically separate from one another. The signal cables between the safety control equipment and ACTIVE Cube must either be physically separate from one another or suitable, cross fault proof cables.
- Comply with applicable EMC instructions mentioned in the operating instructions.
- After installation, check the safety function and error reaction and issue an acceptance report.
- Interrupting the STO signals prevents a start of the motor. According to EN 60204-1, STO must not be released during an impending endangerment.
- Also comply with the instructions on external safety control equipment.
- During commissioning, check the safety function.

Select the dimensions of the safety application such that 14 mA input current is available for each of the inputs STOA and STOB. If more than one ACTIVE Cube frequency inverters are connected to one safety control device, the safety control device must provide sufficient power for all of them.

7.2 External Safety Control Equipment

Safety control equipment, upon request (e.g. actuation of emergency stop or access to hazard area, must trigger appropriate responses in order to protect people, the machine and the environment. They evaluate sensor signals or safely switch off dangerous states.

External safety control devices must meet the following requirements:

- External safety control equipment and safety modules for control of the digital inputs (STO) must meet one of the following classifications, to meet the classification of the ACU device:
 - o PL d according to EN ISO 13849-1
 - o SIL 2 according to IEC 61508
 - o Category 3 according to EN 954-1
 - o the whole installation meets these requirements
- The switching capacity of the safety control equipment must be designed for the maximum permissible, limited output current of the DC 24 V power supply. Comply with the instructions of the manufacturer of the safety control equipment on the permissible contact load and any safeguards to be provided for the safety contacts.
- The emergency stop device must comply with Standard EN ISO 13850.
- If a safety request (e.g. emergency stop actuated or sensor signals that safety door is open) is reset (emergency stop unlocked, safety door closed) this alone shall not result in a restart of the drive. Restart may only occur after the safety control device has been reset.

External safety control devices evaluate sensors:

Examples of contact sensors:

- Emergency stop control device for stop in dangerous situations
- Position switch, e.g. for monitoring slide doors, safety grids or moving machine parts

Examples of no-contact sensors:

- Light barriers, e.g. for monitoring areas with dangerous movements
- Light curtains

7.3 External DC 24 V power supply

During projection and installation of a DC 24 V supply connected to the frequency inverter comply with the following instruction. This also includes supply of a safety control device the output of which is connected to a control input (including STOA and STOB) of the frequency inverter.



CAUTION

Use a suited SELV/PELV voltage supply, which rated voltage has to be DC 24 V $\pm 10\%$. The largest overvoltage must not exceed DC 32 V in the case of a fault (one fault safety). The one fault safety has to be realized with an overvoltage protection of the mains supply (overvoltage protection OVP with limiting the output voltage to a maximum of DC 32 V) or an external wiring like a Crowbar. An adequate overvoltage category of the voltage supply has to be ensured.

7.4 DC 24 V Power supply by ACU

You can use terminal X210A.1 in order to supply a safety control device. Only use the power supply for the device connected to the frequency inverter. Other safety control devices **must not** be connected. The maximum output current is 180 mA. The connected device must not have higher current requirements.

8 Requirements to be met in operation

During operation, the projected and commissioned machine components must not be changed. If the machine is modified a new acceptance inspection is required.

Check the safety function at regular intervals. The test intervals are to be determined according to the risk analysis. However, the check should be performed once every year, at the latest.

9 Requirements to be met by acceptance inspection

The acceptance inspection of the safety function is ordered by the manufacturer of the machine. The inspection (acceptance) shall be performed by a properly qualified person.

The result of the inspection is to be documented and must be signed by the inspector. Each safety function must be documented in detail in this report.

The inspections also include the machine documentation, including its safety functions. The safety functions must be checked particularly during the inspection and documented in the inspection report. Parameter settings shall be attached to the report. Further documents shall be added, as required, depending on the machine.

Depending on the result of the risk analysis, inspection reports of the regular inspections shall be issued and signed by the inspector.

10 Application Examples

The following examples illustrate how the “Safe Torque Off” function works. According to EN 60204, stop functions are divided in different categories. By suitable safety control devices, stop categories 0 and 1 can be realized in combination with the frequency inverter ACU.

Stop category 0: Stop by immediate disconnection of energy supply to the machine drive elements, i.e. uncontrolled stop.

Stop category 1: Controlled stop, where energy is still being supplied to the drive elements of the machine to perform the stopping operation. Energy supply is stopped only after the drive has come to a standstill.

Stop functions must always have priority over start functions and must work properly in any operation mode.

Resetting of the stop function must not cause any dangerous state.

The mechanical elements must be dimensioned properly for the stop category used. If, for example, a mechanical brake is applied in the case of fast-rotating machines via stop category 0, this brake must be able to stop the machine safely. Wear and tear of the mechanical elements must be considered during projection for the operating states and indicated in the maintenance instructions.

Stop category 0 always has priority over stop category 1.

10.1 Direct Stop, Stop Category 0

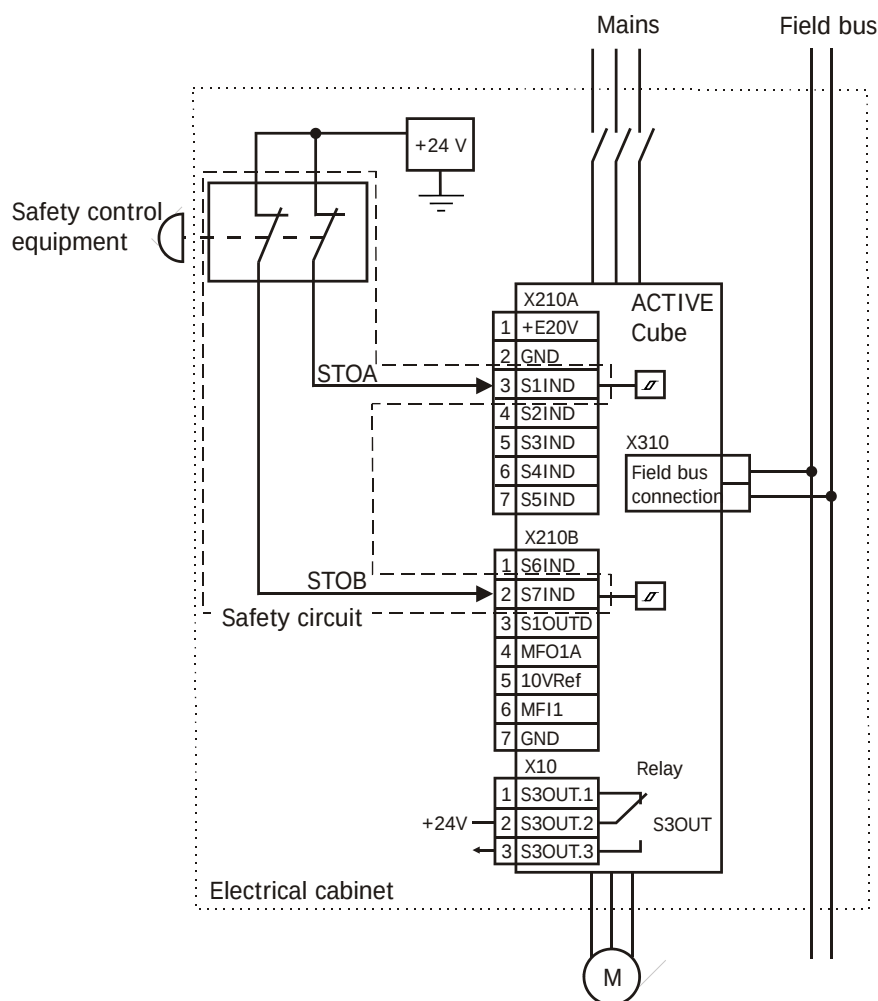
The application example shows the minimum circuitry for ACTIVE cube frequency inverters for realization of the safety function STO "Safe Torque Off" with an emergency stop device in a common electrical cabinet.

If the emergency stop device with two stop channels according to EN ISO 13849-1 PL d, IEC 61508 SIL 2 or EN954-1 Category 3 is actuated, both stop paths STOA and STOB of the ACTIVE Cube frequency inverter are interrupted and the integrated safety function with safe pulse block with SIL 2 according to EN-61800-5-2 is activated.

A (non-safe) feedback to a process controller can be effected, for example, via a connected field bus. If STO is requested, the overriding controller has no more influence on the pulse block in the frequency inverter.



Terminal X210A.1 can be used for DC 24 V supply of the safety control unit. Please note the current capacity of the frequency inverter (and the current requirements of the safety control device).



STOA: first shutdown path of the safety function STO

STOB: second shutdown path of the safety function STO

X210A, X210B, X10: Control terminals of the frequency inverter

X310: Interface of communication module

+E20V: DC 20 V voltage output or input for an external DC 24 V voltage supply

Terminal X210A.2 : Earth 20 V/ Earth 24 V (ext.)

S1IND ... S7IND: Digital inputs

S1OUTD: Digital output

MFO1A: Multi-function output (analog/digital, frequency signal)

10VRef: Reference voltage DC 10 V

MFI1A: Multi-function input (analog/digital)

Terminal 210B.7: Earth 10 V

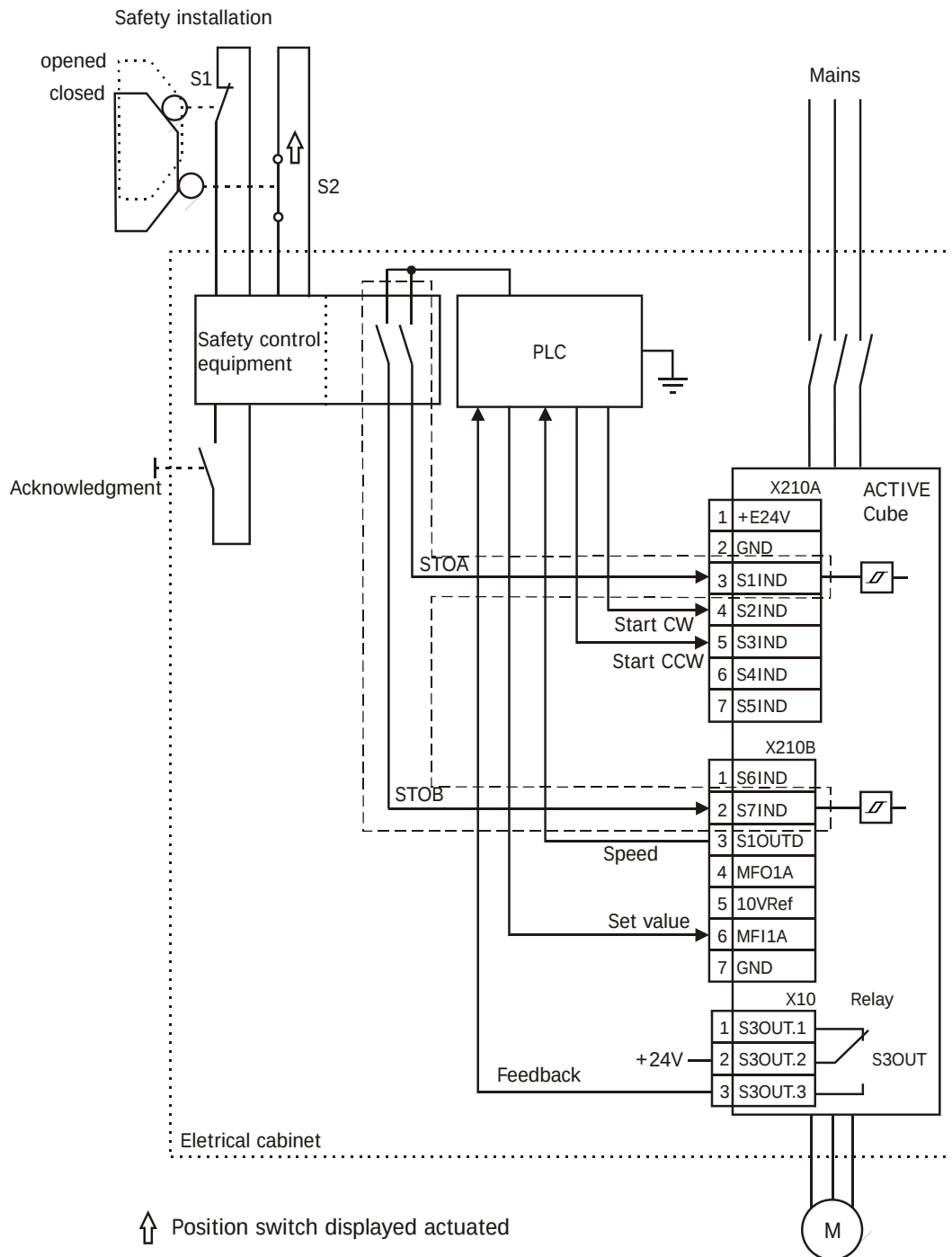
X10: Relay output

10.2 Direct Stop with Feedback to PLC, Stop Category 0

The application circuit shows a drive control system according to EN ISO 13849-1 PL d, IEC 61508 SIL 2 or EN 954-1 category 3 with PLC and safety module. A PLC performs the process control of the frequency inverter and can start the drive profiles via commands.

If the protective device is actuated, e.g. safety door open, the enable paths of the safety module are interrupted. As a result, the controller enable signal of the frequency inverter is interrupted via the disconnection of the control voltages from STOA and STOB and the integrated safe pulse block is activated.

The safety module monitors the function of the switches S1 and S2 which are located outside of the electrical cabinet.

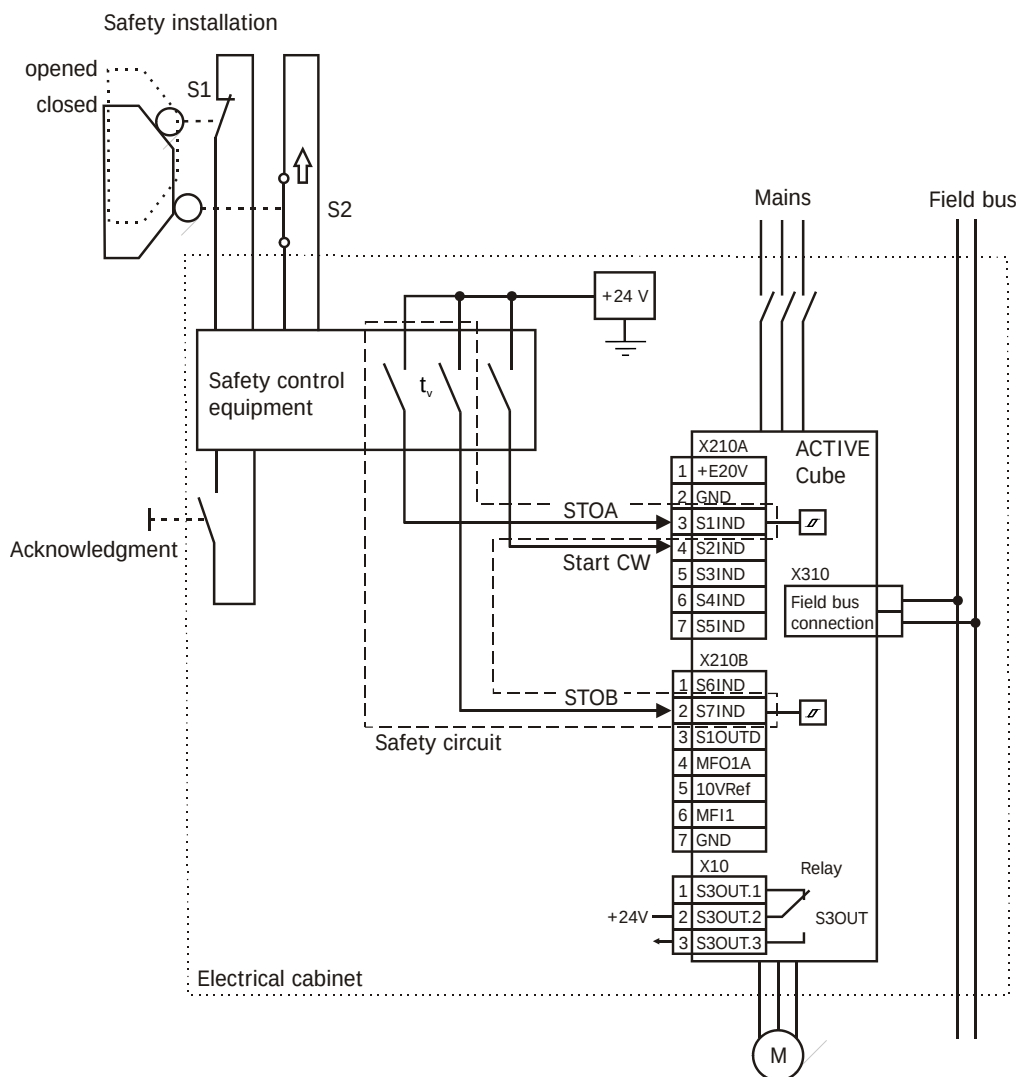


10.3 Direct Stop, Stop Category 1

The application example shows the minimum circuitry for ACTIVE cube frequency inverters for realization of the safety function STO "Safe Torque Off" with an emergency stop device in a common electrical cabinet.

When the emergency stop device is actuated, the travel command "Clockwise" is reset first. After a delay t_v , the contacts on the safety switch interrupt the two enable paths STOA and STOB of the ACTIVE Cube frequency inverter and the integrated safety function is activated. The delay time is set on the safety control device and must be selected according to the application. The set delay time has to be higher than the shut down time.

A (non-safe) feedback to a process controller can be effected, for example, via a connected field bus. If STO is requested, the overriding controller has no more influence on the pulse block in the frequency inverter.



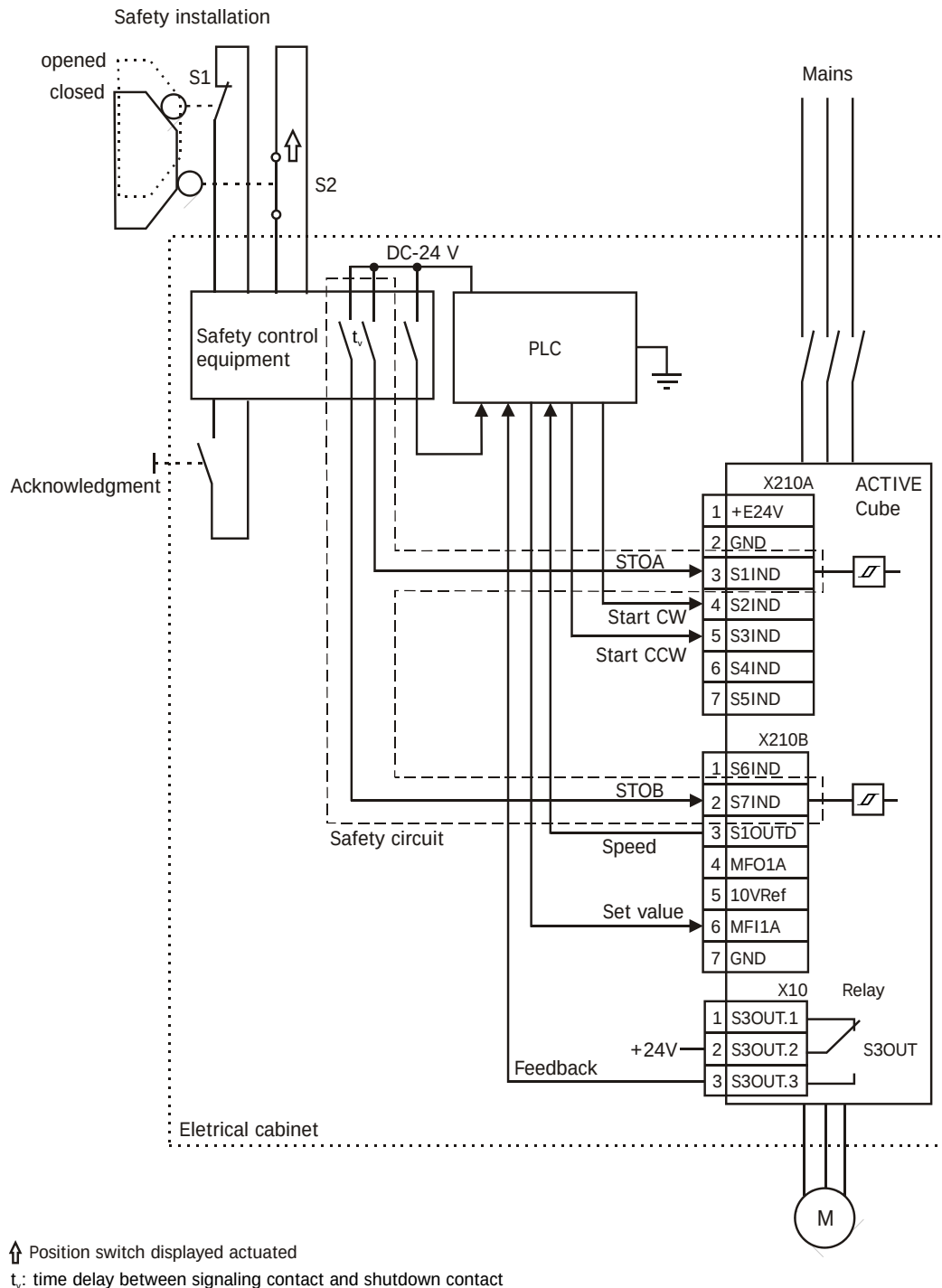
- STOA: first shutdown path of the safety function STO
- STOB: second shutdown path of the safety function STO
- X210A, X210B, X10: Control terminals of the frequency inverter
- X310: Interface of communication module
- +E20V: DC 20 V voltage output or input for an external DC 24 V voltage supply
- Terminal X210A.2 : Earth 20 V/ Earth 24 V (ext.)
- S1IND ... S7IND: Digital inputs
- S1OUTD: Digital output
- MFO1: Multi-function output (analog/digital, frequency signal)
- 10VRef: Reference voltage DC 10 V
- MFI1: Multi-function input (analog/digital)
- Terminal 210B.7: Earth 10 V
- X10: Relay output
- ⬆ Position switch displayed actuated
- t_v : time delay between signaling contact and shutdown contact

10.4 Direct Stop with Feedback to PLC, Stop Category 1

The application circuit shows a drive control system according to EN ISO 13849-1 PL d, IEC 61508 SIL 2 or EN 954-1 category 3 with PLC and safety module. A PLC performs the process control of the frequency inverter and can start the drive profiles via commands.

If the protective device is actuated, e.g. safety door open, the enable paths of the safety module are interrupted. At first, the PLC is informed about the fact that the safety function has been triggered. Then, the PLC decelerates the motor in a controlled way by resetting the direction of rotation (S2 or S3). After a delay t_v , the controller enable signal of the frequency inverter is interrupted via the disconnection of the control voltages from STOA and STOB and the integrated safe pulse block is activated.

The safety module monitors the function of the switches S1 and S2 which are located outside of the electrical cabinet.

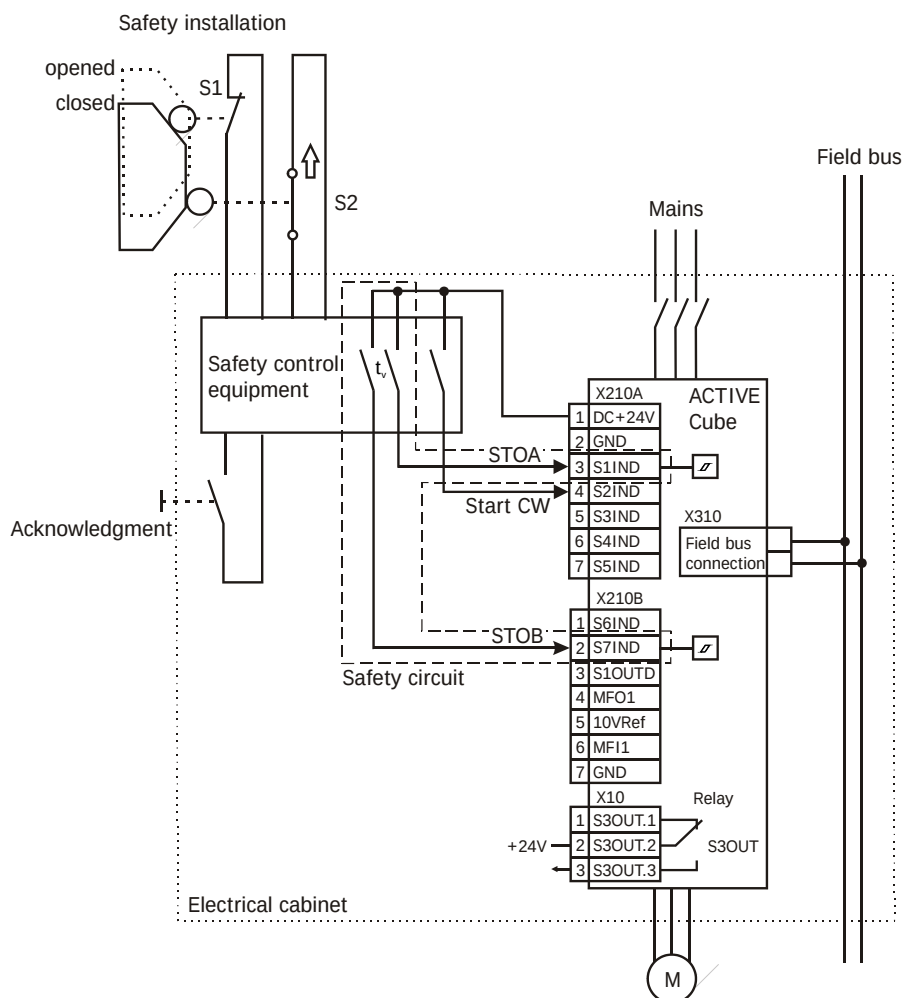


10.5 Internal DC 24 V Supply, Stop Category 1

The application example shows the minimum circuitry for ACTIVE cube frequency inverters for realization of the safety function STO "Safe Torque Off" with an emergency stop switch in a common electrical cabinet. Supply of the safety control device is effected by the internal DC 24 V supply (max. 180 mA).

When the emergency stop switch is actuated, the travel command "Clockwise" is reset first. After a delay t_v , the contacts on the safety switch interrupt the two enable paths STOA and STOB of the ACTIVE Cube frequency inverter and the integrated safety function is activated. The delay time is set on the safety control device and must be selected according to the application. The delay time is set on the safety control device and must be selected according to the application. The set delay time has to be higher than the shut down time.

A (non-safe) feedback to a process controller can be effected, for example, via a connected field bus. If STO is requested, the overriding controller has no more influence on the pulse block in the frequency inverter.



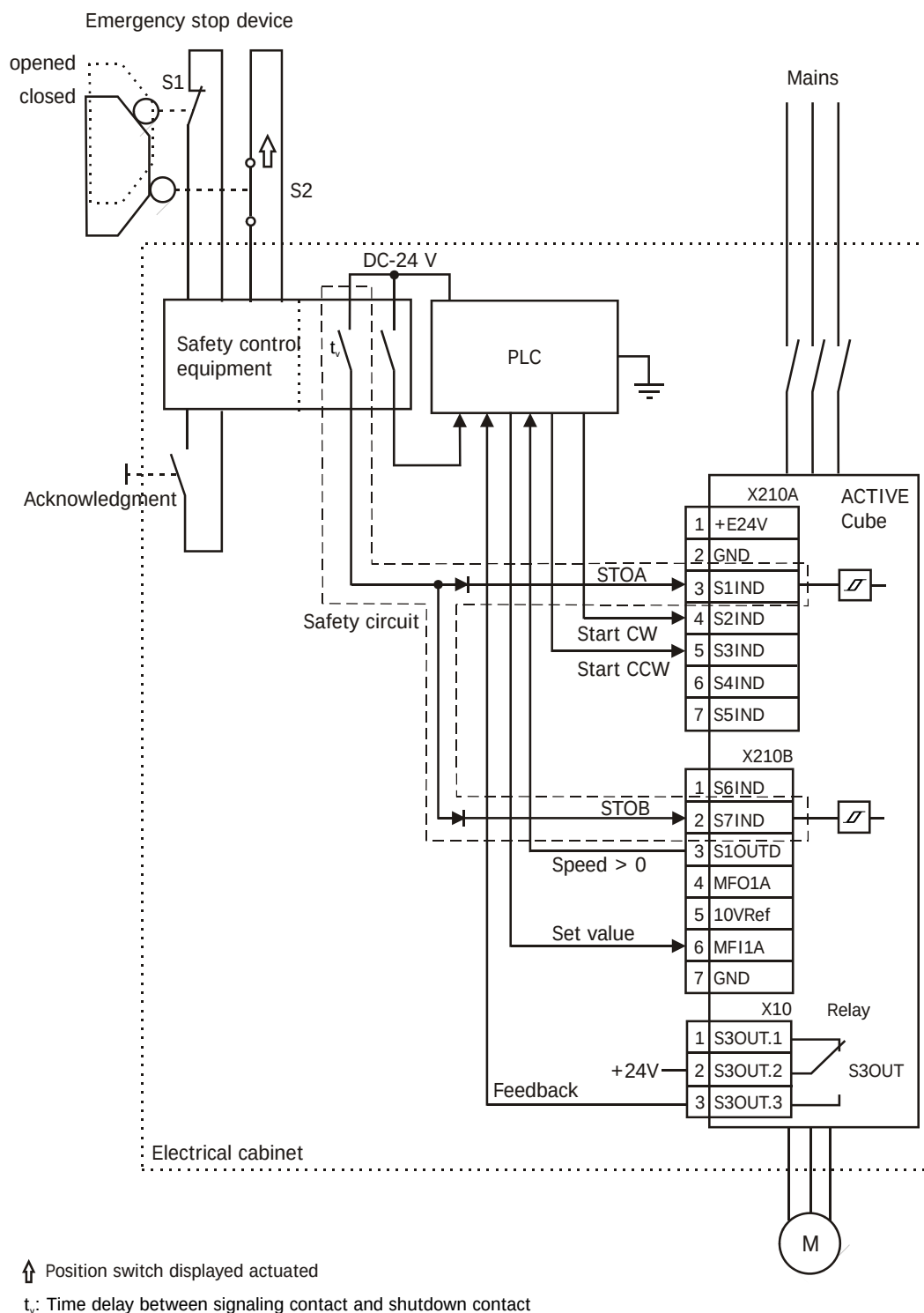
STOA: first shutdown path of the safety function STO
 STOB: second shutdown path of the safety function STO
 X210A, X210B, X10: Control terminals of the frequency inverter
 X310: Interface of communication module
 +E20V: DC 20 V voltage output or input for an external DC 24 V voltage supply
 Terminal X210A.2 : Earth 20 V/ Earth 24 V (ext.)
 S1IND ... S7IND: Digital inputs
 S1OUTD: Digital output
 MFO1: Multi-function output (analog/digital, frequency signal)
 10VRef: Reference voltage DC 10 V
 MF11: Multi-function input (analog/digital)
 Terminal 210B.7: Earth 10 V
 X10: Relay output
 ⬆ Position switch displayed actuated
 t_v : time delay between signaling contact and shutdown contact

10.7 Error exclusion “short circuit” in the cabinet

The application circuit shows a drive control system according to EN ISO 13849 PL d, IEC 61508 SIL 2 or EN 954-1 category 3 with PLC and safety control equipment. Safety control equipment with one enable path and interconnection line is implemented instead of safety control equipment with two enable paths.

Comply with the following conditions:

- Safety control equipment and inverter have to be placed in the same cabinet.
- Error exclusion in case of short circuit has to be ensured for wiring between safety control equipment and inverter (for example insulated conductor).
- Blocking diodes have to be integrated into each path after separation of the STO inputs.



11 Checklist

This list provides an overview of the requirements to be met in installation, commissioning and operation of the safety function. Depending on the application, additional requirements must be met. Complete this list according to your application.

Risk analysis:

- was performed
- requires the use of the safety function “Safe Torque Off”
- requires category 3 according to the following classifications:
 - PL d (or smaller) according to EN ISO 13849-1
 - SIL 2 (or smaller) according to IEC 61508
 - Category 3 (or smaller) according to EN 954-1
- considers the stopping behavior of the ACTIVE Cube frequency inverter
- permits coasting of the drive to a standstill or requires the installation of a mechanical brake.
- considers the access time to the hazard area
- defines intervals for regular functional checks of the safety function

Installation:

- EMC instructions in the operating instructions considered?
- The shield of the 24 V power supply was connected on both sides.
- Emergency stop devices meet the following classifications:
 - PL d (or smaller) according to EN ISO 13849-1
 - SIL 2 (or smaller) according to IEC 61508
 - Category 3 (or smaller) according to EN 954-1
- Emergency Stop devices have a cross fault monitoring (2-channel connection) or protected wiring?
- It is ensured that resetting of the safety control device alone does not result in a restart of the drive.
- It is ensured that no voltage higher than DC 30 V can occur on the terminals of the control electronic unit (voltage resistance).
- The protection against unexpected restart is set up.

Commissioning:

- Functional check of safety function performed?
- Wiring of safety components checked?
- Acceptance report issued?

Operation:

- The safety function is checked regularly.

12 Safety Function Test Report

The concept relating to the safety function STO (Safe Torque Off) described in this manual was assessed and certified by Berufsgenossenschaftliches Institut für Arbeitsschutz (Trade Association Institute for Work Safety).

Test institute	Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung
Test report no.	200622803
Test sample	Frequency inverter of ACTIVE Cube series, concept inspection
Basis of test	DIN EN 61508 Parts 1-7:2002/2005 (as far as applicable)
	DIN EN ISO 13849-2:2003 (as far as applicable)
	EN 13849 -1:2006-11
	DIN EN 954-1:1997-03
	DIN EN 62061
	DIN EN 61800-5-1
	IEC 61800-5-2:2007
	DIN EN 61800-3
Assessment	Due to the realized error tolerance and the measures for error management, error prevention and error identification, the presented concept meets the requirements up to safety integrity level SIL 2 according to DIN EN 61508, category 3 according to DIN EN 954-1 as well as performance level d according to EN 13849-1.

13 STO status (diagnosis)

The actual value STO state 277 can be used for an extended diagnosis of the two inputs STOA and STOB. The states of the inputs are displayed bit coded.

Bit	Significance	Description
0	1	Input STOA missing
1	2	Input STOB missing
2	4	Input STOA switch off
3	8	Input STOB switch off
4	16	Timeout STOA
5	32	Timeout STOB
6	64	Diagnosis fault
7	127	Frequency Inverter fault (error)

14 Index of Change

ACU-STOV1-01SV2-04: General and Safety instructions adapted to actual Bonfiglioli Vectron documentations, information in chapter 3 according to EN 60204 revised.

ACU-STOV1-01SV2-03: Clarification of Emergency stop and emergency switch off in chapter 1.1 of the English version. Note for transition period of EN954-1 in chapter 2 updated.

ACU-STOV1-01SV2-02: Terminal designation of relay output X10 changed.

ACU-STOV1-00SV2-02: New Application example Fault exclusion "Short circuit" in electrical cabinet. Application examples 8.2 and 8.4 changed to display the usage of the digital output more precise.

ACU-STOV1-00SV2-01: Different supplements and more detailed descriptions

ACU-STOV1-00SV1-01: Changed DC-24 V into DC 24 V and DC-30 V into DC 30 V.

ACU-STOV1-00SV1-00: First issue

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